CHAPTER 12

BASIC DIAGRAMS AND SYSTEMS

In the preceding chapters, you learned about hydraulic and pneumatic fluids and components of fluid power systems. While having a knowledge of system components is essential, it is difficult to understand the interrelationship of these components by simply watching the system operate. The knowledge of system interrelation is required to effectively troubleshoot and maintain a fluid power system. Diagrams provided in applicable technical publications or drawings are a valuable aid in understanding the operation of the system and in diagnosing the causes of malfunctions.

This chapter explains the different types of diagrams used to illustrate fluid power circuits, including some of the symbols that depict fluid power components. Included in this chapter are descriptions and illustrations denoting the differences between open-center and closed-center fluid power systems. The last part of the chapter describes and illustrates some applications of basic fluid power systems.

DIAGRAMS

As mentioned earlier in this chapter, to troubleshoot fluid power systems intelligently, a mechanic or technician must be familiar with the system on which he or she is working. The mechanic must know the function of each component in the system and have a mental picture of its location in relation to other components. This can best be done by studying the diagrams of the system.

A diagram may be defined as a graphic representation of an assembly or system that indicates the various parts and expresses the methods or principles of operations. The ability to read diagrams is a basic requirement for understanding the operation of fluid power systems. Understanding the diagrams of a system requires having a knowledge of the symbols used in the schematic diagrams.

SYMBOLS

The Navy uses two military standards that list mechanical symbols that must be used in preparing drawings that will contain symbolic representation. These standards are as follows:

1. *Military Standard, Mechanical Symbols (Other than Aeronautical, Aerospacecraft, and Spacecraft Use), Part 1,* MIL-STD-17B-1.
2. *Military Standard, Mechanical Symbols for Aeronautical, Aerospacecraft, and Spacecraft Use, Part 2,* MIL-STD-17B-2.

Some of the symbols frequently used in fluid power systems have been selected from these two standards and are shown in Appendixes II and III. Appendix II contains symbols from MIL-STD-17B-1. Appendix III contains symbols from MIL-STD-17B-2.

While the symbols shown in the appendixes are not all encompassing, they do provide a basis for an individual working with fluid power systems to build upon. Some rules applicable to graphical symbols for fluid diagrams are as follows:

1. Symbols show connections, flow paths, and the function of the component represented only. They do not indicate conditions occurring during transition from one flow path to another; nor do they indicate component construction or values, such as pressure or flow rate.
2. Symbols do not indicate the location of ports, direction of shifting of spools, or position of control elements on actual components.
3. Symbols may be rotated or reversed without altering their meaning except in cases of lines to reservoirs and vented manifolds.
4. Symbols may be drawn in any size.
5. Each symbol is drawn to show the normal or neutral condition of each component unless multiple circuit diagrams are furnished showing various phases of circuit operation.

For more detailed information concerning the symbols used in fluid power diagrams, consult the above-mentioned military standards. Additional information concerning symbols and the reading of diagrams is contained in *BIueprint Reading and Sketching,* NAVEDTRA 10077-F1.

TYPES OF DIAGRAMS

There are many types of diagrams. Those that are most pertinent to fluid power systems are discussed in this text.

Pictorial Diagrams

Pictorial diagrams (fig. 12-1) show the general location and actual appearance of each component, all interconnecting piping, and the general piping arrangement. This type of diagram is sometimes referred to as an installation diagram. Diagrams of this type are invaluable to maintenance personnel in identifying and locating components of a system.

Cutaway Diagrams

Cutaway diagrams (fig. 12-2) show the internal working parts of all fluid power components in a system. This includes controls and actuating mechanisms and all interconnecting piping. Cutaway diagrams do not normally use symbols.

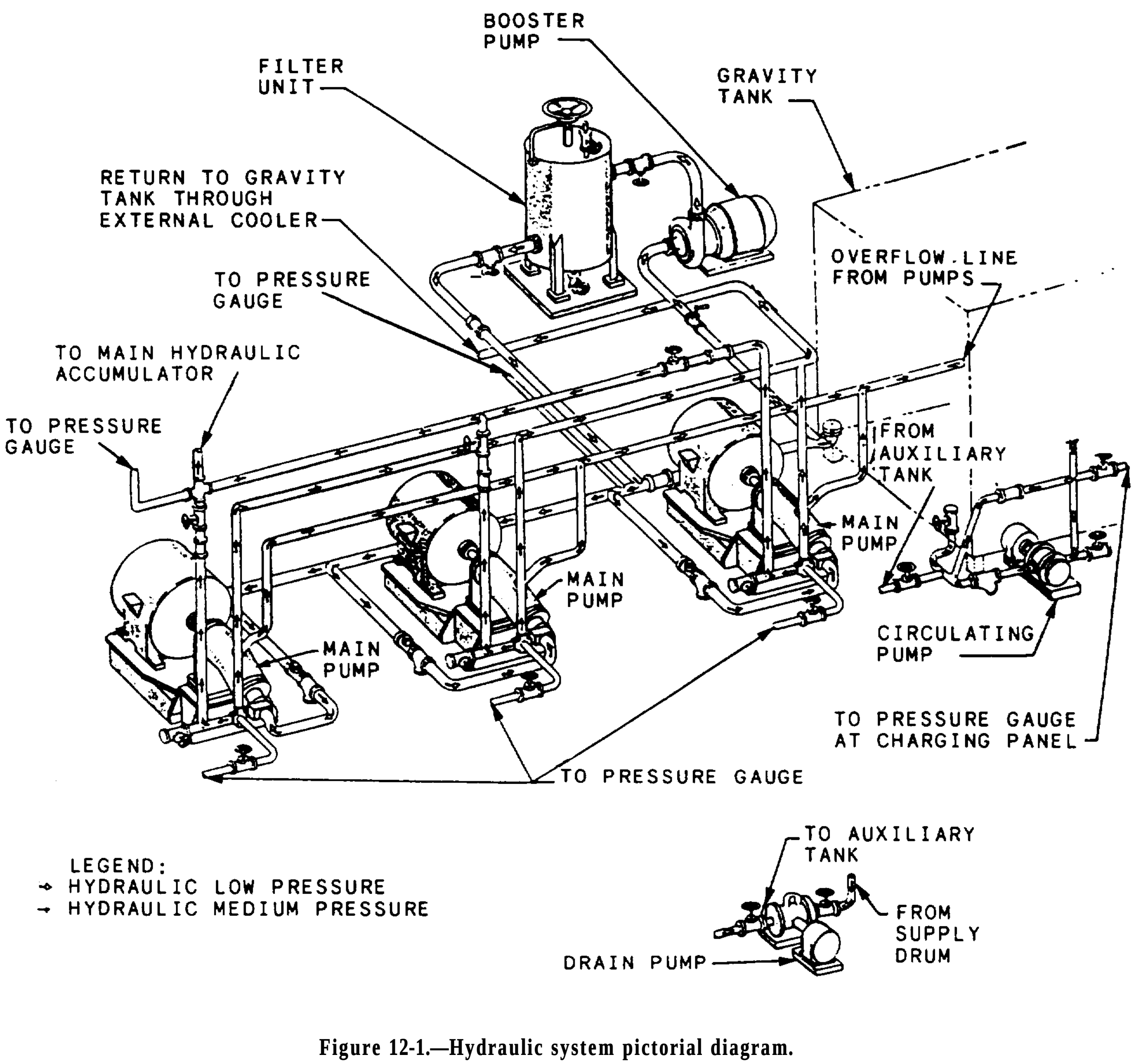


Figure 12-1.—Hydraulic system pictorial diagram.

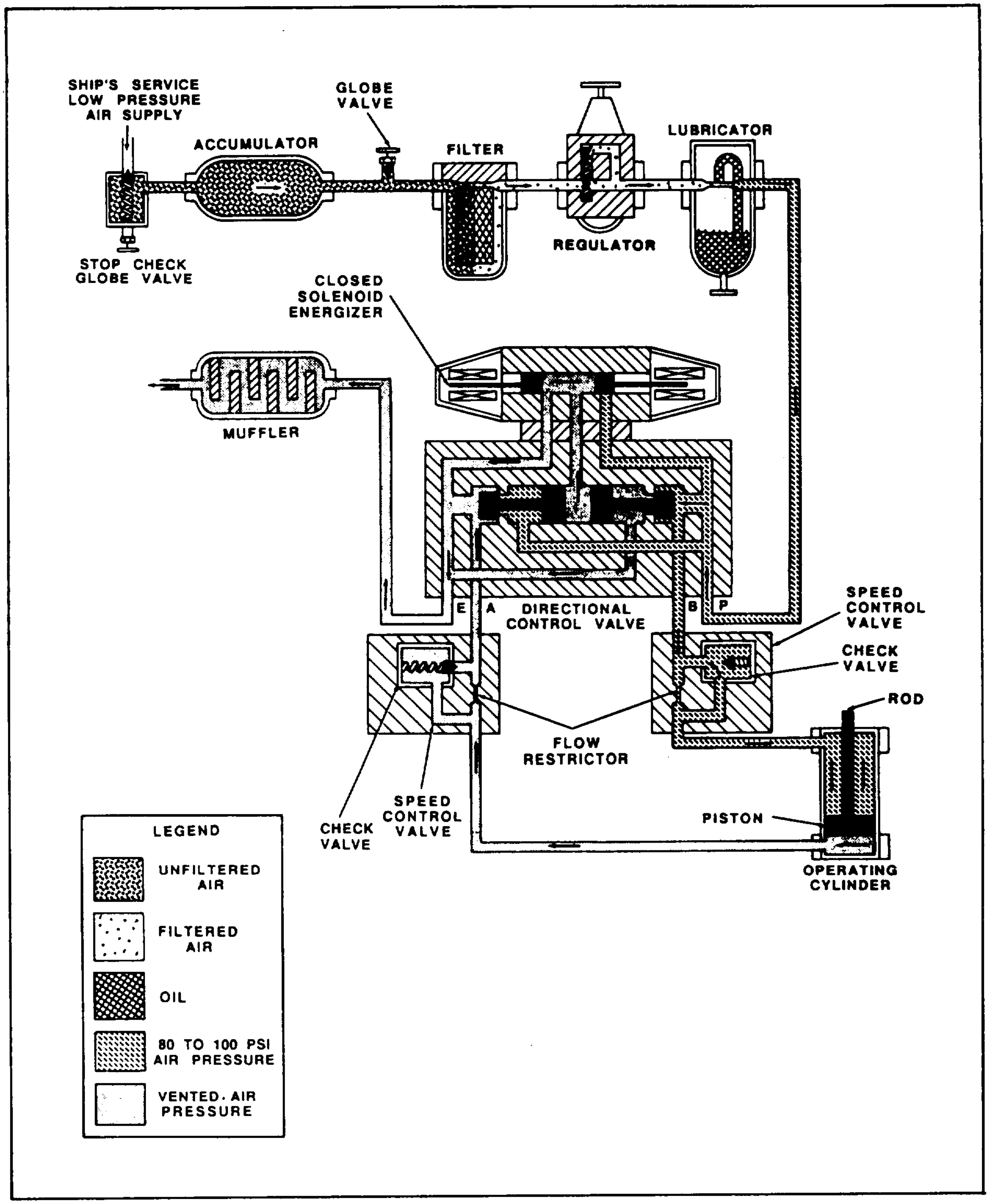
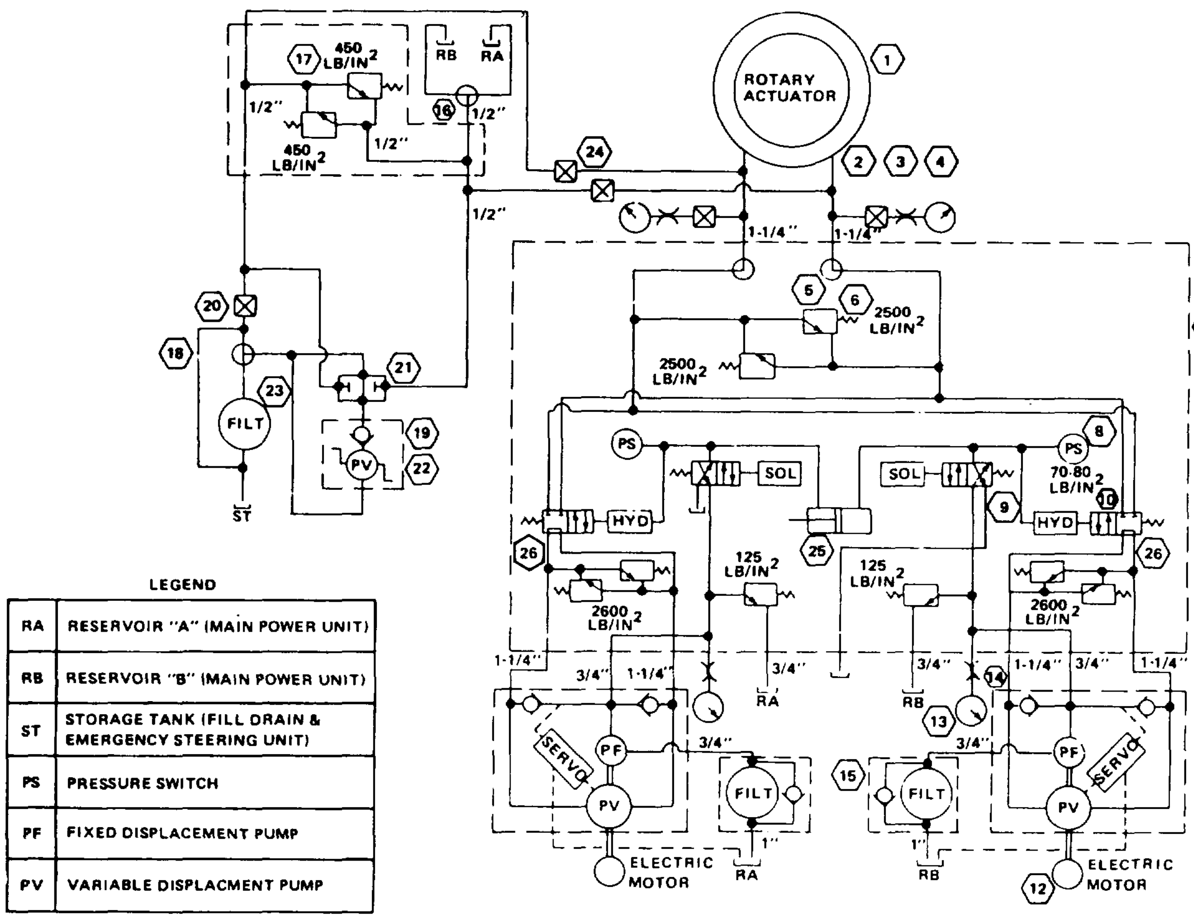


Figure 12-2.—Cutaway diagram—pneumatic.

Graphic Diagrams

The primary purpose of a graphic (schematic) diagram is to enable the maintenance person to trace the flow of fluid from component to component within the system. This type of diagram uses standard symbols to show each component and includes all interconnecting piping. Additionally, the diagram contains a component list, pipe size, data on the sequence of operation, and other pertinent information. The graphic diagram (fig. 12-3) does not indicate the physical location of the various components, but it does show the relation of each component to the other components within the system.



1. Rotary actuator
2. 1 1/4-inch shutoff valve
3. 0-5000 psi pressure snubber
4. 0-3000 psi pressure gauge
5. Manual 1-inch rotary selector valve
6. Pressure control valve
7. Manifold block
8. 7-250 psi pressure switch
9. 1/4-inch solenoid-operated 4-way valve
10. 3/4-inch pilot-operated 4-way valve
11. None
12. Electric motor (see NOTE)
13. 0-300 psi pressure gauge
14. Servo-operated variable-displacement pump
15. 10-micron filter
16. 1/2-inch manual rotary selector valve
17. Pressure control valve
18. 1/2-inch manual rotary selector valve
19. Common check valve with hand pump
20. 1/2-inch shutoff valve
21. 3/8-inch manual rotary selector valve
22. Hand pump
23. 10-micron filter
24. Shutoff valve
25. LVR/LVP selector cylinder
26. Relief valves

NOTE: Electric Motor is 40 horsepower, 1800 rpm, 440 volts ac, 3 phase, 60 hertz.

Figure 12-3.—Graphic diagram of LST 1182 class hydraulic steering gear.

Notice that figure 12-3 does not indicate the physical location of the individual components with respect to each other in the system. For example, the 3/4-inch, solenoid-operated, 4-way valve (10) is not necessarily located directly above the relief valve (26). The diagram does indicate, however, that the 4-way valve is located in the working line, between the variable-displacement pump and the 1-inch rotary selector valve, and that the valve directs fluid to and from the rotary actuator.

Combination Diagrams

A combination drawing uses a combination of graphic, cutaway, and pictorial symbols. This drawing also includes all interconnecting piping.

FLUID POWER SYSTEMS

A fluid power system in which the fluid in the system remains pressurized from the pump (or regulator) to the directional control valve while the pump is operating is referred to as a closed-center system. In this type of system, any number of subsystems may be incorporated, with a separate directional control valve for each subsystem. The directional control valves are arranged in parallel so that system pressure acts equally on all control valves.

Another type of system that is sometimes used in hydraulically operated equipment is the open-center system. An open-center system has fluid flow but no internal pressure when the actuating mechanisms are idle. The pump circulates the fluid from the reservoir, through the directional control valves, and back to the reservoir. (See fig. 12-4, view A.) Like the closed-center system, the open-center system may have any number of subsystems, with a directional control valve for each subsystem. Unlike the closed-center system, the directional control valves of an open-center system are always connected in series with each other, an arrangement in which the system pressure line goes through each directional control valve. Fluid is always allowed free passage through each control valve and back to the reservoir until one of the control valves is positioned to operate a mechanism.

When one of the directional control valves is positioned to operate an actuating device, as shown in view B of figure 12-4, fluid is directed from the pump through one of the working lines to the actuator. With the control valve in this position, the flow of fluid through the valve to the reservoir is blocked. Thus, the pressure builds up in the system and moves the piston of the actuating cylinder. The fluid from the other end of the actuator returns to the control valve through the opposite working line and flows back to the reservoir.

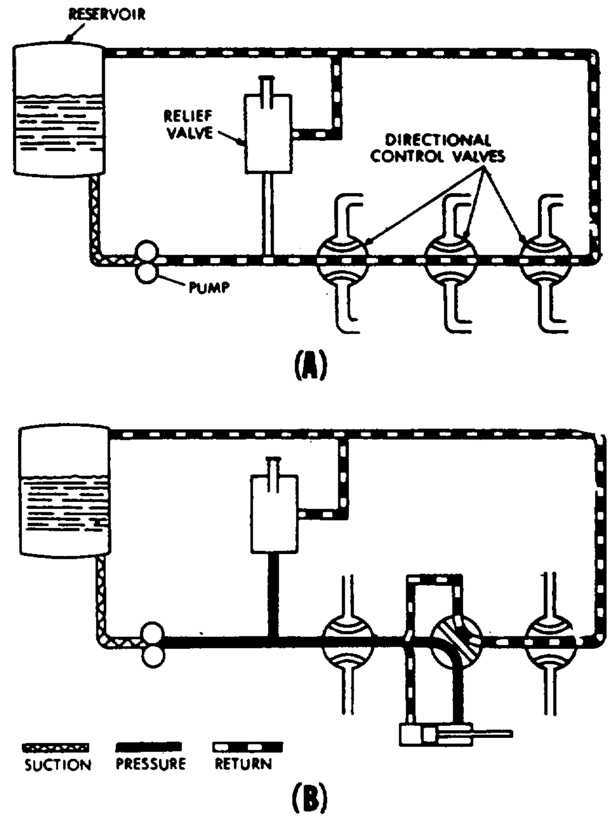


Figure 12-4.—Open-center hydraulic system.

Several different types of directional control valves are used in the open-center system. One type is the manually engaged and manually disengaged. After this type of valve is manually moved to the operating position and the actuating mechanism reaches the end of its operating cycle, pump output continues until the system relief valve setting is reached. The relief valve then unseats and allows the fluid to flow back to the reservoir. The system pressure remains at the pressure setting of the relief valve until the directional control valve is manually returned to the neutral position. This action reopens the open-center flow and allows the system pressure to drop to line resistance pressure.

Another type of open-center directional control valve is manually engaged and pressure disengaged. This type of valve is similar to the valve discussed in the preceding paragraph; however, when the actuating mechanism reaches the end of its cycle and the pressure continues to rise to a predetermined pressure, the valve automatically returns to the neutral position and, consequently, to open-center flow.

One of the advantages of the open-center system is that the continuous pressurization of the system is eliminated. Since the pressure is gradually built up after the directional control valve is moved to an operating position, there is very little shock from pressure surges. This provides a smooth operation of the actuating mechanisms; however, the operation is slower than the closed-center system in which the pressure is available the moment the directional control valve is positioned. Since most applications require instantaneous operation, closed-center systems are the most widely used.

HYDRAULIC POWER DRIVE SYSTEM

The hydraulic power drive has been used in the Navy for many years. Proof of its effectiveness is that it has been used to train and elevate nearly all caliber guns, from the 40-mm gun mount to the 16-inch turret. In addition to gun mounts and turrets, hydraulic power drives are used to position rocket launchers and missile launchers, and to drive and control such equipment as windlasses, capstans, and winches.

In its simplest form, the hydraulic power drive consists of the following:

1. The prime mover, which is the outside source of power used to drive the hydraulic pump
2. A variable-displacement hydraulic pump
3. A hydraulic motor
4. A means of introducing a signal to the hydraulic pump to control its output
5. Mechanical shafting and gearing that transmits the output of the hydraulic motor to the equipment being operated

Hydraulic power drives differ in some respects, such as size, method of control, and so forth. However, the fundamental operating principles are similar. The unit used in the following discussion of fundamental operating principles is representative of the hydraulic power drives used to operate the 5"/38 twin mounts.

Figure 12-5 shows the basic components of the train power drive. The electric motor is constructed with drive shafts at both ends. The forward shaft drives the A-end pump through reduction gears, and the after shaft drives the auxiliary pumps through the auxiliary reduction gears. The reduction gears are installed because

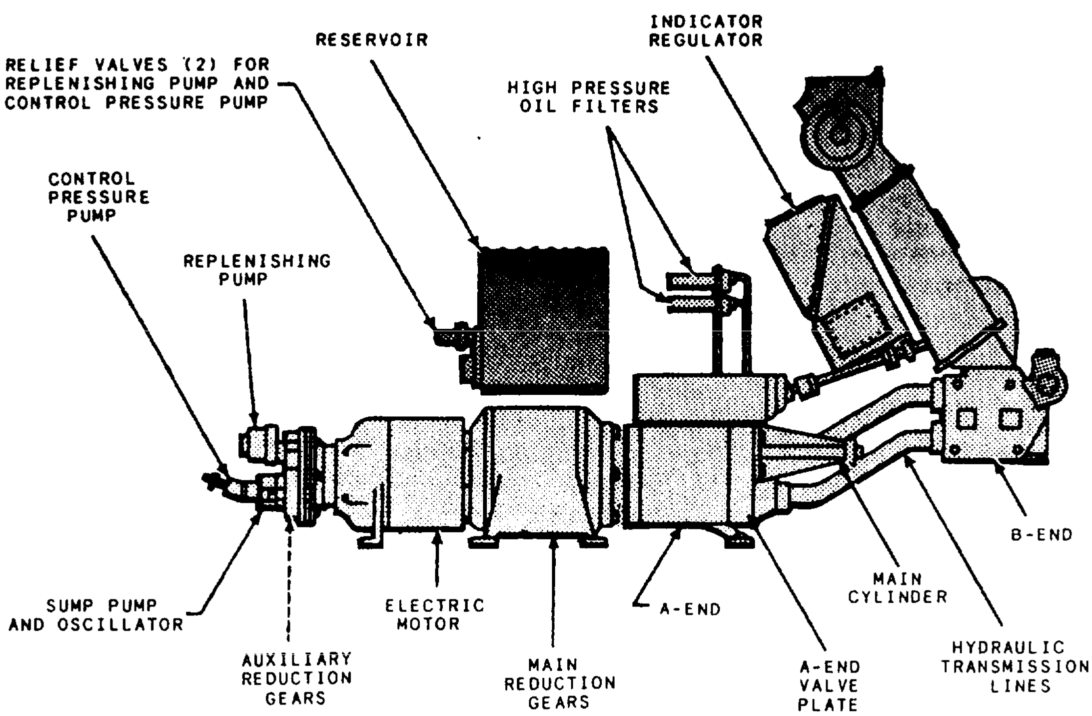


Figure 12-5.-Train power drive—components.

the pumps are designed to operate at a speed much slower than that of the motor.

The replenishing pump is a spur gear pump. Its purpose is to replenish fluid to the active system of the power drive. It receives its supply of fluid from the reservoir and discharges it to the B-end valve plate. This discharge of fluid from the pump is held at a constant pressure by the action of a pressure relief valve. (Because the capacity of the pump exceeds replenishing demands, the relief valve is continuously allowing some of the fluid to flow back to the reservoir.)

The sump pump and oscillator has a twofold purpose. It pumps leakage, which collects in the sump of the indicator regulator, to the expansion tank. Additionally, it transmits a pulsating effect to the fluid in the response pressure system. Oscillations in the hydraulic response system help eliminate static friction of valves, allowing hydraulic control to respond faster.

The control pressure pump supplies high-pressure fluid for the hydraulic control system, brake pistons, lock piston, and the hand-controlled clutch operating piston. The control pressure pump is a fixed-displacement, axial-piston type. An adjustable relief valve is used to limit the operating pressure at the outlet of the pump.

Control

For the purpose of this text, control constitutes the relationship between the stroke control shaft and the tilting box. The stroke control shaft is one of the piston rods of a double-acting piston-type actuating cylinder. This actuating cylinder and its direct means of control are referred to as the main cylinder assembly (fig. 12-6). It is the link between the hydraulic followup system and the power drive itself.

In hand control, the tilting box is mechanically positioned by gearing from the handwheel through the A-end control unit. In local and automatic control, the tilting box is positioned by the stroke control shaft. As shown in figure 12-6, the extended end of the control shaft is connected to the tilting box. Movement of the shaft will pivot the tilting box one way or the other; which, in turn, controls the output of the A-end of the transmission. The other end of the shaft is attached to the main piston. A shorter shaft is attached to the opposite side of the piston. This shaft is also smaller in diameter. Thus the working area of the left side of the piston is twice that of the area of the right side, as it appears in figure 12-6.

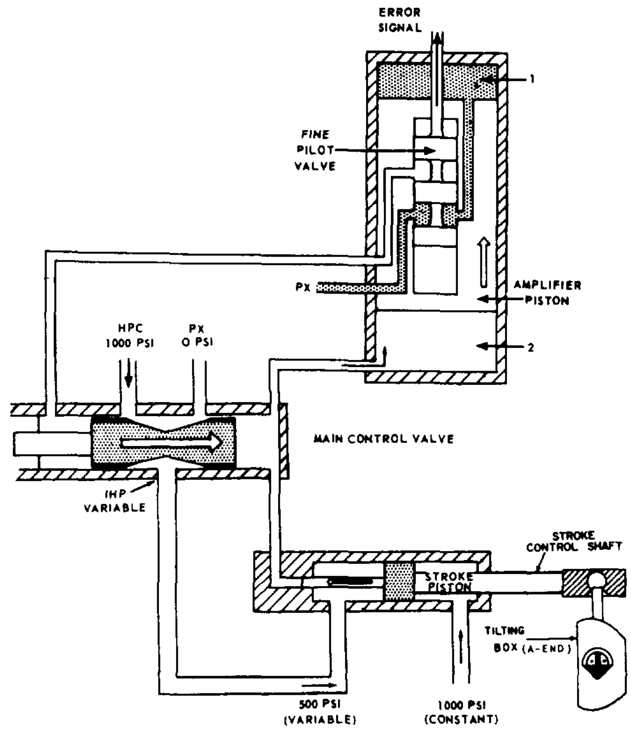


Figure 12–6.–Main cylinder assembly.

Intermediate high-pressure fluid (IHP) is transmitted to the left side of the piston, while high-pressure hydraulic fluid (HPC) is transmitted to the right side. The HPC is held constant at 1000 psi. Since the area of the piston upon which HPC acts is exactly one-half the area upon which IHP acts, the main piston is maintained in a fixed position when IHP is one-half HPC (500 psi). Whenever IHP varies from its normal value of 500 psi, the main piston will move, thus moving the tilting box.

Operation

Assume that a right train order signal is received. This will cause the pilot valve to be pulled upward. The fluid in the upper chamber of the amplifier piston can now flow through the lower land chamber of the fine pilot to exhaust. This will cause the amplifier piston to move upward, and the fluid in the right-hand chamber of the main control valve can flow into the lower chamber of the amplifier valve.

The main control valve will now move to the right, IHP will drop below 500 psi, and the stroke piston will move to the left. Movement of the stroke piston will cause tilt to be put on the tilt plate, and the A-end will cause the mount to train right.

Figure 12-7 is a simplified block diagram showing the main element of the hydraulic power drive system under automatic control for clockwise and counterclockwise rotation.

There are two principal problems in positioning a gun to fire. One is to get an accurate gun-order signal. This problem is solved by the director-computer combination. The other problem is to transmit the director signal promptly to the gun so that the position and movements of the gun will be synchronized with the signals from the director.

The problem of transforming gun-order signals to mount movements is solved by the power drive and its control—the indicator regulator. The indicator regulator controls the power drive, and this, in turn, controls the movement of the gun.

The indicator regulator receives an initial electrical gun-order from the director-computer, compares it to the existing mount position, and sends an error signal to the hydraulic control mechanism in the regulator. The hydraulic control mechanism controls the flow to the stroke control shaft, which positions the tilting box in the A-end of the transmission. Its tilt controls the volume and direction of fluid pumped to the B-end and, therefore, the speed and direction of the drive shaft of the B-end. Through mechanical linkage, the B-end output shaft moves the gun in the direction determined by the signal. At the same time, B-end response is transmitted to the indicator regulator and continuously combines with incoming gun-order signals to give the error between the two. This error is modified hydraulically, according to the system of mechanical linkages and valves in the regulator. When the gun is lagging behind the signal, its movement is accelerated; and when it begins to catch up, its movement is slowed down so that it will not overrun excessively.

LANDING GEAR EMERGENCY SYSTEM

If the landing gear in a naval aircraft fails to extend to the down and locked position, the aircraft has an emergency method to extend the landing gear. This text will cover the nitrogen system.

The nitrogen storage bottle system is a one-shot system powered by nitrogen pressure stored in four compressed nitrogen bottles (fig. 12-8). When the landing gear control handle is used to actuate the emergency landing gear system, a cable between the control and the manually operated nitrogen bottle opens the emergency gear down release valve on the bottle. Nitrogen from this bottle actuates the release valves on the other three bottles so that they discharge. Nitrogen flows from the manually operated bottle, actuates the dump valves, and causes the shuttles within the shuttle valves on the

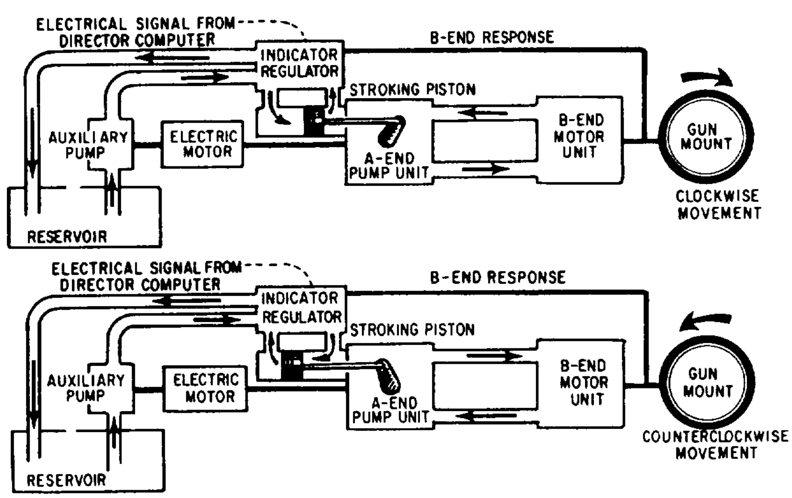


Figure 12-7.—Operation of the hydraulic power drive.

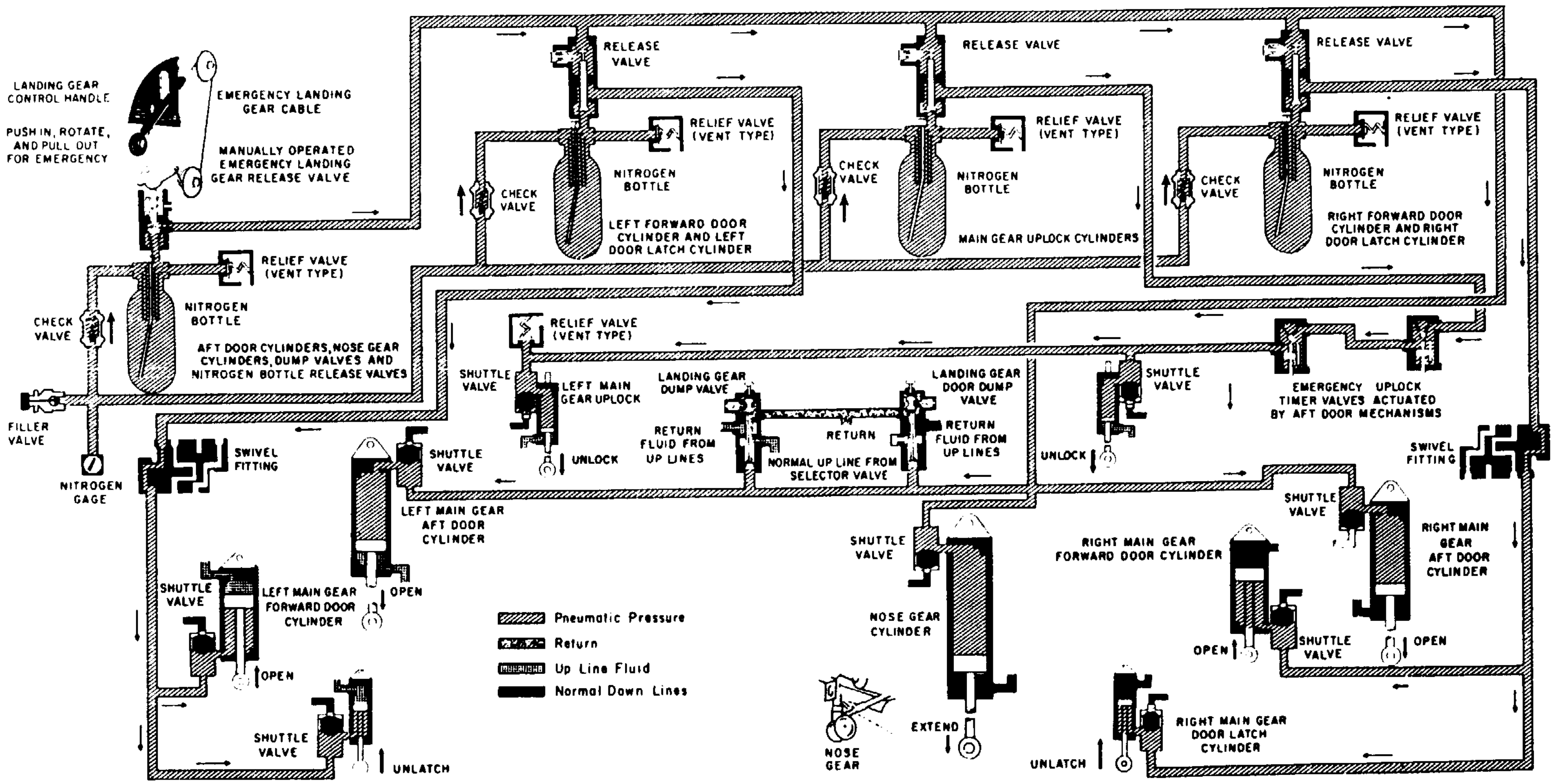


Figure 12-8.—Landing gear emergency extension system.

aft doors' cylinders and the shuttle valve on the nose gear cylinder to close off the normal port and operate these cylinders. The nose gear cylinder extends; this unlocks the uplock and extends the nose gear. The nitrogen flowing into the aft door cylinders opens the aft doors. Fluid on the close side of the door cylinder is vented to return through the actuated dump valves. Nitrogen from another bottle actuates the shuttle valves on the uplock cylinders. Nitrogen flows into the uplock cylinders and causes them to disengage the uplocks. As soon as the uplocks are disengaged, the main gear extends by the force of gravity. Fluid on the up side of the main gear cylinders is vented to return through the actuated dump valves, preventing a fluid lock.

JET BLAST DEFLECTORS

Jet blast deflectors (JBD) onboard aircraft carriers are raised and lowered by hydraulic cylinders through mechanical linkage. Two hydraulic cylinders are attached to each JBD panel shaft by crank assemblies. (See fig. 12-9.) The shaft is rotated by the push and pull operation of the hydraulic cylinders. Shaft rotation extends or retracts the linkage to raise or lower the JBD panels. This operation is designed so that in the event of a failure of one of the hydraulic cylinders, the other one will raise or lower the panels.

Figure 12-10 is a diagram of the hydraulic control system of a JBD during the raise cycle. Hydraulic fluid from the catapult hydraulic supply system is supplied to the JBD hydraulic system through an isolation valve and a filter to the 4-way control valve assembly. (The 4-way control valve assembly consists of a pilot-operated control valve, a direct- or solenoid-operated control valve, and a sequence valve, which is not shown.)

To raise the JBD, solenoid B of the 4-way control valve assembly is energized. The spools of the 4-way valve assembly shift, allowing medium-pressure hydraulic fluid to flow into port A of the hydraulic cylinder. The cylinders extend,

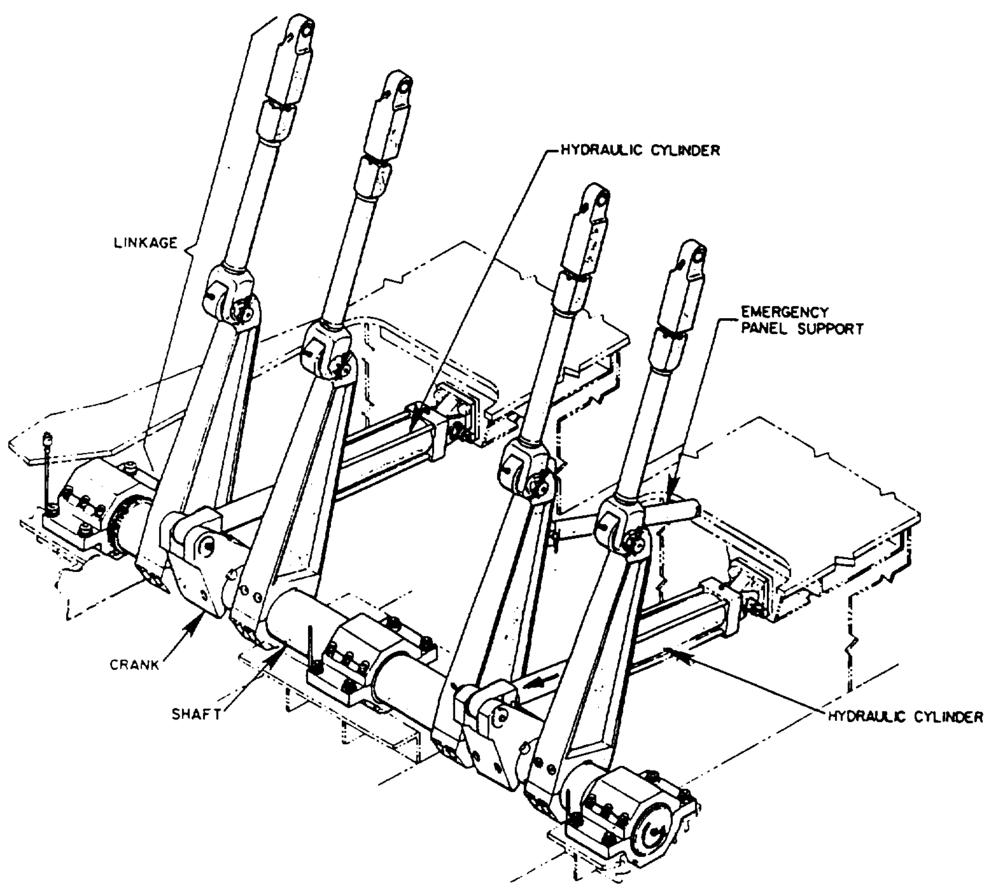


Figure 12-9.—Operating gear assembly (panels raised).

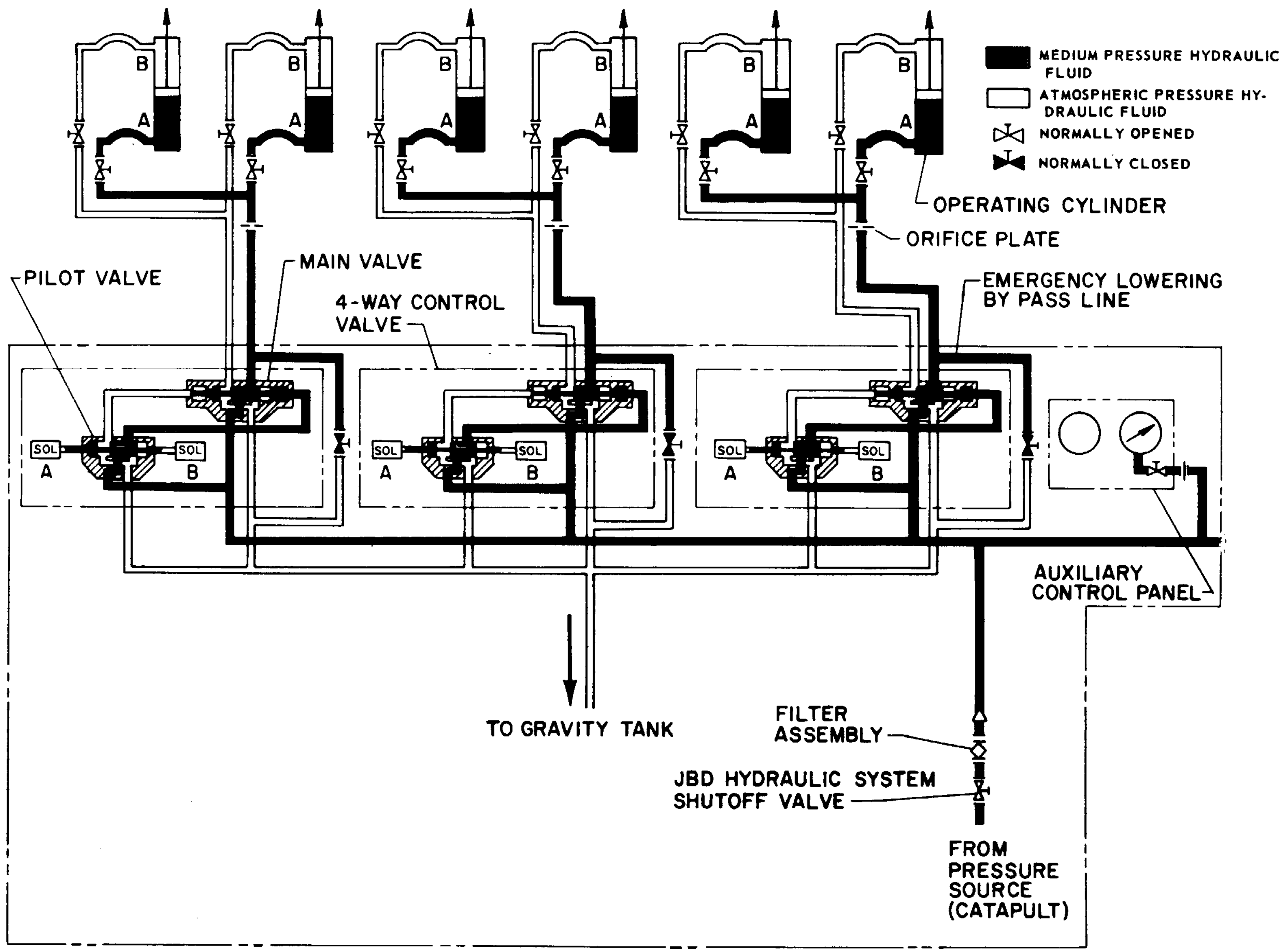


Figure 12-10.—Hydraulic system flow diagram, raise cycle.

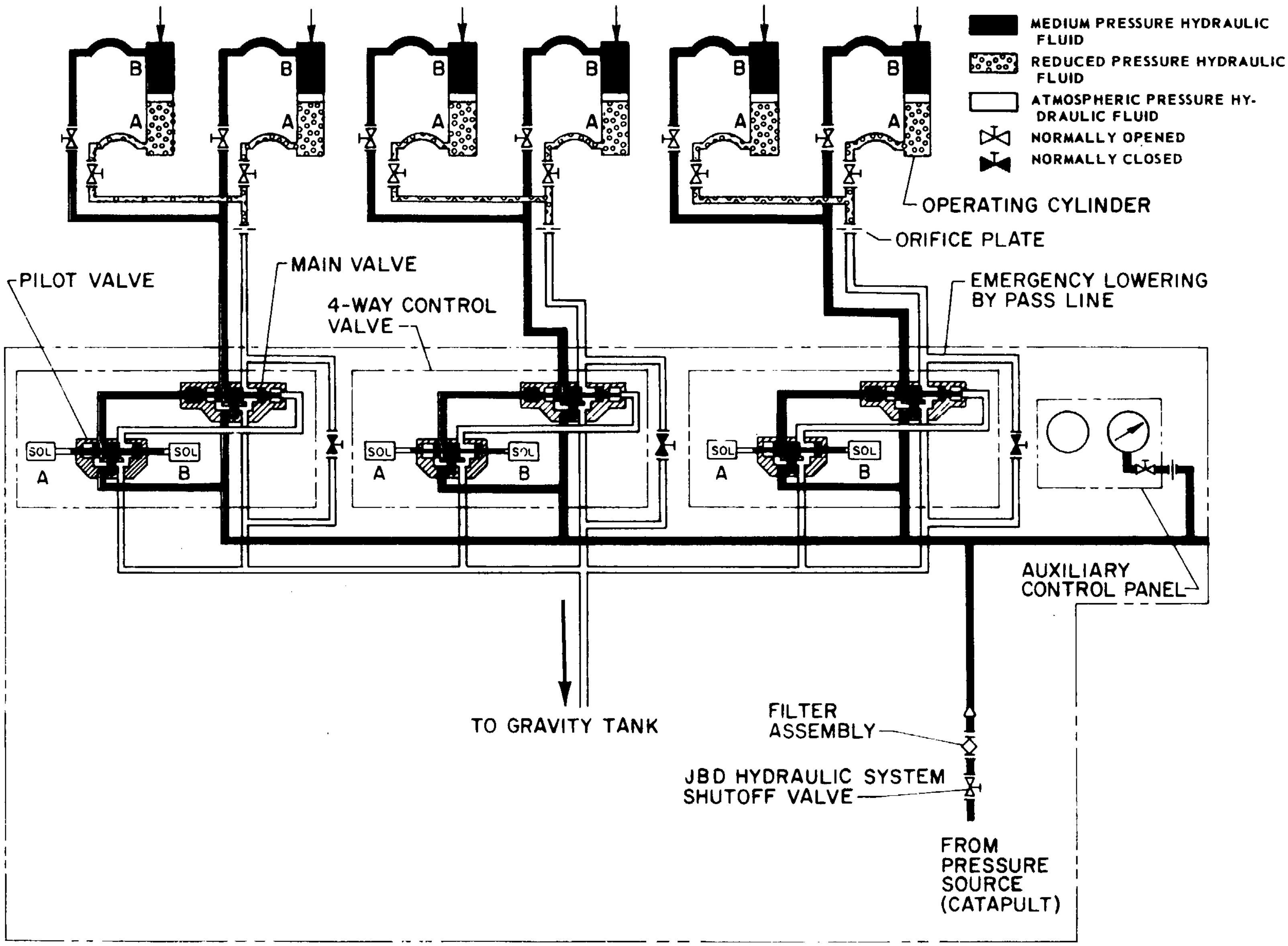


Figure 12-11.—Hydraulic system flow diagram, lower cycle.

pushing the crank assembly aft and rotating the shaft. The rotation of the shaft extends the operating gear linkage and raises the panel assemblies. Fluid from port B of the piston is directed through the 4-way valve assembly and back to the gravity tank.

To lower the JBD (fig. 12-11), solenoid A of the 4-way control valve assembly is energized. The spools of the 4-way valve assembly shift, allow medium-pressure hydraulic fluid to flow into port B of the hydraulic cylinder. The cylinders retract, pulling the crank assembly forward and rotating the shaft. The rotation of the shaft retracts the operating gear linkage and lowers the panel assemblies. Fluid from port A of the piston is directed through the 4-way valve assembly and back to the gravity tank.

To lower the JBD in the event of hydraulic control failure, each JBD panel is equipped with a manual bypass valve, which allows bypassing the 4-way control valve. This allows venting the hydraulic pressure from the "raise" side of the cylinder back to the gravity tank.

The three lines to port A of the hydraulic cylinders have orifice assemblies in them. These orifice assemblies control the flow of hydraulic fluid in both the raise and lower operations.